DESCARTES' THEORY OF ELEMENTS: FROM *LE MONDE* TO THE *PRINCIPES*

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When one traces the development of Descartes' philosophy of nature from *Le Monde* (1633) through the *Discours* (1637), *Dioptrique* (1637), and *Météores* (1637), to the *Principes* (1647),[1] one finds that the explanatory power of the theory of elements, initially developed in his *Traité de la Lumière* but suppressed in the *Discours* and only briefly stated in the *Dioptrique* and *Météores*, is both sharpened and extended in the *Principes*. Though in *La Lumière* Descartes somewhat tentatively rejects the existence of a void, in the *Principes* acceptance of a void constitutes one of the principal errors inhibiting the advance of knowledge. Descartes develops his corpuscularian theory of matter in *La Lumière* principally to account for the nature of light (especially its instantaneous transmission), but in the *Principes* the corpuscularian theory of matter and the theory of elements constitute two of the basic principles which explain *all* natural phenomena in the visible world (light being only one of such phenomena). Somewhat sketchily developed in *La Lumière*, his claim that extension is the essence of a body (suggested earlier in the incomplete *Regulae*[2] and his discussions with Beeckman[3]) requires in the *Principes* a lengthy discussion of the notions of space, place, and situation. In short, the philosophy of nature of the *Principes* (1647) is not merely a restatement of that of *La Lumière* (1633); it is much more a clarification, extension, and revision of that earlier work. The cosmogony of *La*

[1] All references to Descartes' writings shall be to *Oeuvres de Descartes*, ed. Charles Adam and Paul Tannery (Paris, 1897-1910), 13 vols. (abbreviated, *AT*). All references to Descartes' letters are to *Correspondance*, ed. Charles Adam and Gaston Milhaud (Paris, 1936-63), 8 vols. (abbreviated, *AM*). Whenever possible, I shall refer in the main body of the essay to the relevant sections of the *Traité de la Lumière* (by chapter and paragraph) and *Les Principes de la Philosophie* (by part and section) (abbreviated, *LaL* and *P* respectively). Unless otherwise specified, all translations are my own. I have used the French text of the *Principes* of 1647, supplemented where necessary by the Latin edition of 1644, since in my judgment the French translation by Abbé Picot, carefully reviewed and revised by Descartes himself, is the more authoritative text.

[2] See especially Rules XII, XIII, and XIV of his *Regulae ad Directionem Ingenii*, *AT*, X, 359-469. Cf. his letter to Beeckman of 26 March 1619 (*AM*, I, 5-11).

[3] See Jack Vrooman, *René Descartes: A Biography* (New York, 1970), Chap. 2; and John Schuster, *Descartes and the Scientific Revolution (1618-1634)* (Princeton University Dissertation, 1977), unpublished.

Lumière has become in the *Principes* a cosmology as well.[4] Since in my judgment the theory of elements is a major component of Descartes' philosophy of nature. I shall undertake to examine the development and role of his theory of elements.

This is an important, though somewhat neglected, task[5] because it enables us to understand more fully why Descartes suppressed publication of his *Traité de la Lumière* despite pleas from his friends that he publish it.[6] Descartes was reluctant to publish *La Lumière* primarily (though not exclusively) because he thought his corpuscularian theory of matter and theory of elements would be both misunderstood and distorted by being taken simply as another heretical form of atomism. Of course, there is no question that Galileo's condemnation by the Catholic Church in 1633 played an important role in Descartes' decision not to publish *La Lumière* shortly after its completion in that same year; his correspondence of this period makes that clear.[7] However, following Lasswitz, I am suggesting only that there were other matters that concerned Descartes during the years in which he was composing this treatise that may have weighed more heavily upon his decision not to publish it. After all, in 1624 the Parlement of Paris had shockingly condemned, under punishment of death, the public teach-

[4] For convenience, I shall stipulate the difference between a cosmogony and cosmology as follows. By "cosmogony" I shall mean an account only of the origins of the fundamental order of the present universe. By "cosmology" I shall mean, in addition, an account of all the various phenomena (e.g., magnetism, heat, etc.) of the present universe. In this use, a cosmology includes a cosmogony but not vice-versa. I should also point out here that Descartes emphasizes in both *La Lumière* and Part III of the *Principes* the "hypothetical" character of his cosmogony.

[5] The pioneer in this regard is Kurd Lasswitz, "Zur Genesis der Cartesischen Corpuscularphysik," *Vierteljahrsschrift für Wissenschaftliche Philosophie*, **10** (1886), 166-89, incorporated with some modifications and additions in his classic *Geschichte der Atomismus von Mittelalter bis Newton* (Hamburg, 1890), Vol. II, Chap. 3. Ivor Leclerc's provocative interpretation of Descartes (*The Nature of Physical Existence* [London, 1972], Chaps. 16 and 17) is greatly influenced by Lasswitz. For a criticism of Lasswitz's interpretation, see Ernst Bloch, "Die chemischen Theorien bei Descartes und den Cartesianern," *Isis*, **1** (1913), 590-636. See also R. Hookyas "Het onstaan van de chemische atoomleer," *Tijdschrift voor Philosophie*, **9** (1946-47), 63-136; and Andrew G. van Melsen, *From Atomos to Atom* (Duquesne, 1952; rpt. 1960); and James Collins, "Descartes' Philosophy of Nature," *American Philosophical Quarterly* (1971: Monograph 5).

[6] See Huyghens' letter to Descartes, 31 March 1636 (*AM*, I, 305-06) and Descartes' replies (*AM*, II, 31-41, 167-69); Morin's letter to Descartes, 22 February 1638 (*AM*, II, 118-32) and Descartes' reply (*AM*, II, 310-27); and Descartes' letter to *** (possibly Cerizy), 27 April 1637 (*AM*, I, 356-57). Descartes continually refused Mersenne's requests to publish it (e.g., 27 April 1637 [*AM*, I, 351-53]).

[7] See his letters to Mersenne, November 1633 (*AM*, I, 242-43), February 1634 (*AM*, I, 250-51), April 1634 (*AM*, I, 252-55), and especially 14 April 1634 (*AM*, I, 264-66), as well as his letter to *** in the Autumn of 1635 (*AM*, I, 284-86).

ing of atomism.[8] The public defense of atomism by de Claves, de Villon, and Bitaud in August of that year had apparently precipitated this condemnation,[9] and it was followed by open prohibition of such doctrines in the halls of the University of Paris and a crisp refutation by Jean Baptiste Morin—an acquaintance with whom Descartes would later correspond about some of the details of his theory of elements.[10] Moreover, Descartes' intimate friendship with Isaac Beeckman, dating from 1618/1619, no doubt influenced the development of his corpuscularian theory of matter (even though Beeckman was an atomist).[11] Indeed, the intellectual milieu of the period, in which questions about the nature and number of elements, the changeability of elements in a mixture, the divisibility of matter, etc., played a rather dominant role, significantly contributed in my judgment to Descartes' concern about the clarity and tenability of his own beliefs concerning these issues.[12] The time Descartes spent in Paris

[8] *Mercure françois* (Paris, 1625), X, 504 ff.; as cited in Lasswitz, *Geschichte der Atomismus von Mittelalter bis Newton*, I, 482 ff.

[9] Jean Bitaud, Antoine de Villon, et Etienne de Claves, *Positiones publicae contra dogmata aristotelica, paracelsica, et cabalistica. . . .* (Paris, 1624).

[10] Jean Baptiste Morin, *Réfutation des thèses erronées d' Antoine Villon, dit le soldat philosophie, et Etienne de Claves médecin-chimiste, par eux affichées publiquement à Paris, contre la doctrine d' Aristote le 23 Août 1624. . . .* (Paris, 1624).

[11] Beeckman was familiar with the new atomistic doctrines of Sebastian Basso, *Philosophia naturalis adversus Aristotelem libri XII* (Geneva, 1621); Daniel Sennert, *Epitome scientiae naturalis* (Wittenberg, 1618) and *De Chymicorum cum Aristotelicis et Galenicis consensu ac dissensu* (Wittenberg, 1619); and Lucillio Vanini, *Ampitheatrum aeternae Providentiae divino-magicum, christiano-physicum, necnon astrologo-catholicum* (Lyons, 1615). See *Journal tenu par Isaac Beeckman de 1604 à 1634*, ed. C. de Waard (The Hague, 1939), II, 100-01 (7-19 August 1620), and II, 243-48 (16 April—6 July 1623), as well as Waard's comments on Beeckman in *Correspondance du P. Marin Mersenne*, ed. C. de Waard (Paris, 1945), II, 118-24. As early as March 26, 1619 (*AM*, I, 7-8), Descartes spoke of a new science which would allow him to solve all the problems of quantity. See also his letter to Beeckman of 17 October 1630 (*AM*, I, 147-63) where he refers to the new philosophy of Basso and Vanini.

[12] There seems little question that two, not entirely independent, developments in the late 16th and early 17th centuries influenced Descartes: (a) a new, essentially anti-Aristotelian philosophy of nature, and (b) the reemergence of a Hermetic philosophy. For a discussion of (a), see Lasswitz, *op. cit.*, I, 306-487; Leopold Mabilleau, *Histoire de la philosophie atomistique* (Paris, 1895); Patricia Reif, "The Textbook Tradition in Natural Philosophy," *Journal of the History of Ideas*, **30** (1969), 17-32; Lynn Thorndike, "Newness and Novelty in 17th Century Science," in *Roots of Scientific Thought*, ed. P. Wiener and A. Noland (New York, 1957), 443-57; Marie Boas Hall, *The Scientific Renaissance, 1450-1630* (New York, 1962); Grant McColley, "Nicolaus Hill and the *Philosophia Epicurea*," *Annals of Science*, **4** (1939), 390-405. For a discussion of (b), see Allen G. Debos, *Alchemy and Chemistry in the 17th Century* (Los Angeles, 1964); Robert S. Westmann, *Hermeticism and the Scientific Revolution* (Los Angeles, 1977); Frances Yates, *Giordano Bruno and the*

from 1625 to 1628 was, as Lasswitz has shown, a formative period in the development of Descartes' philosophy of nature.[13]

All this evidence, however, is indirect. There is more direct evidence for my claim in the works Descartes *published* prior to his *Principes*, during which period some of his friends were complaining that the *Discours* did not adequately delineate the basic principles of his physics.[14] In effect, his summary of *La Lumière* in the *Discours* virtually ignores its first five chapters. The theory of elements, for example, is completely suppressed. No discussion of the void occurs. And in the initial chapter of the *Météores*, where he feels obliged to lay out the basic principles by which he understands phenomena in the visible world, and where one expects to find a discussion of the void and the theory of elements, only a cursory reference to the theory of elements occurs and discussion of the void is eschewed. Since Descartes tells us that he wanted to present in the *Discours only* those principles which would be necessary to illustrate his physics and method and which would be easily understood,[15] it seems fair to infer from the absence of the theory of elements and any discussion of the void, given their reappearance in the *Principes* as central, that Descartes was quite concerned about their clarity and acceptability.[16] To an analysis of his theory of elements we now turn.

Hermetic Tradition (Chicago, 1964); Daniel Walker, *Spiritual and Demonic Magic from Ficino to Campanella* (Notre Dame, 1975); Hélène Metzger, *Les doctrines chimiques en France du début du XIII^e^ à la fin du XVIII^e^ siècle* (Paris, 1923).

[13] See also Ferdinand Alquié, *Descartes* (Paris, 1956). 20-47; Kuno Fischer, *Geschichte der Neuern Philosophie* (Munich, 1878), I, 174-80; Charles Adam, *Descartes, sa vie et son oeuvre* (Paris, 1937), 85-87; Paul Mouy, *Le Développement de la Physique cartésienne* (Paris, 1934), 4-9; J. Sirven, *Les années d'apprentissage de Descartes (1596-1630)* (Paris, 1930); and Joseph Prost, *Essai sur l'atomisme et l'occasionalisme dans la philosophie cartésienne* (Paris, 1907). Descartes' attendance in the autumn of 1627 at a meeting with the papal representative, de Baigne, to hear a lecture by Chandoux seems to have been a turning point in his reflection on some of these matters. See Vrooman, *op. cit.*, 72 ff.

[14] See his letters to Ciermans, 23 March 1638 (*AM*, II, 197-211); to Vatier, 22 February 1638 (*AM*, II, 133 ff.); to Huyghens, 25 February 1637 (*AM*, I, 326-27); and Morin's letter of 22 February 1638 (*AM*, II, 119-32).

[15] See his letters to Mersenne of 15 April 1630 (*AM*, I, 128-32), 25 November 1630 (*AM*, I, 169-73), 23 December 1631 (*AM*, I, 182-84), to Beeckman of 23 August 1634 (*AM*, I, 267-74), to *** (possibly Cerizy) of 27 April 1637 (*AM*, I, 356-57), and to Vatier of 22 February 1638 (*AM*, II, 133 ff.). See also A. I. Sabra, *Theories of Light from Descartes to Newton* (London, 1967), Chap. 1.

[16] See his letters to Villebressieu in the summer of 1631 (*AM*, I, 198-202), to Reneri (?) of 2 June 1631 (*AM*, I, 192-94), to Mersenne of October or November 1631 (*AM*, I, 203-11), and 15 May 1634 (*AM*, I, 256-61), to *** in the autumn of 1635 (*AM*, I, 284-86), and to Pollot of 12 February 1638 (*AM*, II, 92-96). In fragment 8 of Clerselier's edition of Descartes' letters, Descartes claims that his cosmogony is an

(I) In the opening chapters of *Traité de la Lumière*, Descartes develops a "corpuscularian" theory of matter—i.e., matter consists of an indefinitely large number of small parts (indefinitely large because each part is always divisible into smaller parts), such that the behavior of collections of these small parts (i.e., bodies) is a function of the behavior of the smaller parts of which they are composed. Descartes deduces this theory of elements from his experience with various phenomena in the visible world—for instance, fire as it burns wood (*LaL*, II, 2-7). His definition of liquid and solid bodies may serve as an illustration (*LaL*, III, 6-12).

The only difference that Descartes can find to exist between solid and liquid bodies is that the parts of which a liquid body is composed can be more easily moved and separated than those of which a solid body is composed. Accordingly, he defines a solid body (with Aristotle) as one all of whose parts touch without any space remaining between them and without any of the parts acting on one another (i.e., they are at rest) and which thus cohere to form a single body. A liquid body, on the other hand, is one all of whose spherical parts move rapidly in all directions and consequently do not touch each other on all sides. In this respect, both fire and air are regarded by Descartes as liquid bodies. However, Descartes immediately perceives a problem with this account of the motion of the parts of a liquid body (*LaL*, IV, 1): How can the parts move incessantly unless there are empty spaces between them? For Aristotelians, of course, this was a familiar problem in their arguments against the void.[17] Descartes' response to this query is both interesting and cautious.

He admits that he would have difficulty responding if he had not recognized by diverse experiences that all the movements in the world are in some sense circular (as in a vortex) (*LaL*, IV, 5), even though we are not accustomed to observe these circular movements because of our inclination to believe that the air is empty space. Citing the example of fish swimming rapidly in a tank of water, sufficiently below the surface of the water so as not to cause the water to shake, it is clear to Descartes that the water does not shake because the water which the fish push before them does not push indifferently all the water in the tank but only that which can best serve to perfect

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illustration of the basic principles of his physics (*AM*, I, 421-23). His correspondence with Henry More during the latter period of his life reveals the extent to which these issues were still of great concern to him (*AM*, VIII, 90-107, 121-39, 154-85, 204-17).

[17] See, for example, David Furley, "Aristotle and the Atomists on Motion in a Void," in *Motion and Time: Space and Matter*, ed. P. K. Machamer and R. G. Turnbull (Columbus, Ohio, 1976), 83-100; and Edward Grant, "Medieval and 17th Century Conceptions of an Infinite Void beyond the Cosmos," *Isis*, **60** (1969), 42-59.

the circle of their movement and enter the places which they have abandoned (*LaL*, IV, 6). He explains:

> When a body leaves its place, it always enters that of another, and that one into that of another, etc., until the last occupies at the same instant the place relinquished by the first, so that there is no more empty space among them when they are moving than when they are at rest (*LaL*, IV, 8).

What is interesting about this response is the order of the propositions affirmed. The proposition that all motion is circular (as in a whirlpool or vortex) constitutes for Descartes a premise in support of the proposition that there is no void in the visible world.

His response is also cautious, however, since he admits that he cannot prove that a void does not exist. He is certain only that the spaces where we sense nothing in the visible world and which we have been inclined to regard as empty are actually full of the same matter (and of the same amount of matter) as we sense when there is in that place a sensible body. For example, whether a vase is filled with gold, lead, or air, it contains the same matter and the same amount of matter, even though when it contains air, we are inclined mistakenly to believe that there is empty space there (*LaL*, IV, 8-10). While Descartes cannot find any contradiction in affirming the existence of a void *somewhere* in nature, he regards it as *unlikely* in that determinate region to which he has restricted his attention in his cosmogony.[18]

How, then, are we to understand the motion of these parts of matter? To answer this question, Descartes develops his well-known three laws of motion[19]:

> (Law 1) Each individual part of matter remains always in one and the same state, so long as contact with other parts does not compel it to change (*LaL*, VII, 4-9).
> (Law 2) When one body impels another, it cannot impart to it any motion without at the same time losing as much of its own, nor take from it more than that by which its own is increased (*LaL*, VII, 10-13).
> (Law 3) When a body moves, although its movement is most often in a curved line and can never be other than circular in some degree, nevertheless, each of the parts in particular tends always to continue its motion in a straight line (*LaL*, VII, 14-19).

[18] See Edward Grant, "Place and Space in Medieval Physical Thought," in *Motion and Time: Space and Matter*, 137-67.

[19] See Richard Blackwell, "Descartes' Laws of Motion," *Isis*, **57** (1966), 220-34. For a perspective on Descartes' physics, see Paul Tannery, "Descartes physicien," *Revue de métaphysique et morale*, **4** (1896), 478-88, and his *Mémoires scientifiques*, Vol. VI, 451-56.

It is important to remember that for Descartes (Law 1) does not pertain only to motion/rest but to size and figure as well. For example, if *x* has a certain magnitude, it will never become smaller unless it is divided in some way. Similarly, if *y* is round or square, it will never change this figure unless it is compelled to do so. It is also important to bear in mind that in (Law 3) Descartes distinguishes the "tendency to motion" from actual motion; only the former is in the direction of a straight line. Consequently, the same body can tend to move in different directions at the same time (*LaL*, XIII, 1-2).

And what is the nature of the parts of which this matter is composed? It is in response to this question that Descartes develops (in chapter five of *La Lumière*) his theory of elements.

Matter of the first element (E1) is the most subtle and penetrable liquid which exists in the world, all of whose parts are smaller and move more rapidly than any other body in the visible world, and which contain no parts which cannot be easily divided by collisions with other bodies, causing them to change figure, so that they may fit easily through the small intervals that often exist around the other parts of matter. He calls this element "fire."

Matter of the second element (E2) is a subtle liquid (not as subtle as (E1) but more than (E3)) whose parts (in contrast to those of (E1)) have a determinate magnitude and figure, being nearly all spherical, and which are joined together in such a way that the intervals which exist around them are filled with (E1), although these parts of (E1) do not cause the parts of (E2) to change their figure, and whose movement is in some sense uniform. He calls this "air."

Matter of the third element (E3) is a large mass whose parts are quite large (larger than (E1) and (E2)) and have little, if any, movement but which have the power to resist the movement of other bodies, with the consequence that they are not very easily divisible. He calls this "earth."

Descartes readily acknowledges that he makes no use of the traditional qualities (e.g., heat, cold, wet, dry) nor of the Aristotelian notion of primary matter, since in his judgment they are unintelligible and he can explicate these qualities by means only of the movement, figure, magnitude, and arrangement of these elements (*LaL*, V, 6-7). Descartes also feels it important to distinguish his elements from what "the philosophers are wont to call mixtures or compounds" (*LaL*, V, 6). For Descartes, the parts of which these mixtures are composed always contain some qualities which oppose the quality of the composite body, while the parts of the elements must be simple and consequently do not possess any qualities which do not accord so perfectly together that each tends to the preservation of all the others (*LaL*, V, 6). Moreover, in his judgment, all mixed bodies contain

parts which, if reduced, would consist of his three elements (*LaL*, V, 8). For example, the flame (*LaL*, V, 9):

Some of its parts move very rapidly and have a sufficient magnitude to cause the bodies it meets either to diminish in their movement or to break apart (when struck) and decrease their magnitude, as it happens when the bodies which the flame meets are gradually reduced to ashes (E3), or to air and vapor (E2), or to fire (E1).

In sum, then, Descartes feels it important to distinguish his position from both the traditional Aristotelian accounts of matter and more recent theories of matter, deriving in large part from atomism.[20]

We may now turn to Descartes' cosmogony in *La Lumière*. Descartes believes that God initially created matter as:

a true body perfectly solid, which uniformly fills all the length, breadth, and depth of that great space, to which we have restricted our thought, so that each one of its parts always occupies a portion of that space so related to its magnitude that it could not fill a greater, nor contract itself into a less, nor allow, while it remains there, any other body to enter it (*LaL*, VI, 4).

God then sets this matter in motion. However, since there is no void, once God sets any part of this matter in motion, all the other parts of matter must by that same means be set in motion (*LaL*, VII, 1). In accordance with (Law 1), this contact with other parts of matter will cause these parts to change their states (e.g., those moving more rapidly will communicate their motion to those which move more slowly; those larger in size will break up and divide those which are smaller). Moreover, in accordance with (Law 3), each of these parts of matter will be disposed (tend) to move as nearly as possible in the direction of a straight line. However, since there is no void, each of these parts in seeking to move in this way will encounter parts tending to do likewise. Consequently, in accordance with (Law 2), their motion will be circular (as in a vortex). For example, if a body is moving rapidly and tending to proceed in the direction of a straight line, but is prevented from doing so by the resistance of the bodies it meets in its path, like a ball whirled in a sling, this body will actually move along or near the perimeter of the circle which it describes. Of parts of equal size, those with greater speed will describe greater circles, while those of less speed will describe circles closer to the centers. Of parts moving at the same speed, the largest in size will revolve at a greater distance from the centers. And, of those of unequal size and speed, since size always conflicts with speed, the most distant from each

[20] The notion of a "minima naturalia," stemming largely from Arabic commentary on Aristotle, may have played a role in Descartes' thinking here. See van Melsen, *op. cit., passim*.

center will be those which, being a little smaller than those nearer, have also been much swifter. In a short time, therefore, these parts will arrange themselves in a particular order, each part finding itself more or less distant from the center around which it has its course, according to size and speed.

If we pay special attention at this point to the size and speed of these parts, the emergence of the elements will become clear. The original parts of matter would initially be of many different sizes and shapes and would move with differing speeds. However, in striking against one another, eventually some of these parts would have rubbed off, little by little, the small points of their angles and blunted the edges of their sides until they would have become spheres. Descartes calls these spheres matter of the second element (E2). The matter which has broken off the surfaces of (E2) would have acquired a much more rapid motion than those of (E2) and would have become capable of dividing and changing their shape at every moment in order to adapt themselves to the places into which they must fit around these (E2). Descartes calls this matter of the first element (E1). However, some of the parts of this original matter are quite large and have quite irregular shapes since their angles have not been rubbed off nor their edges blunted like (E2). Rather, in striking other parts of matter, they have resisted division and have instead united rather easily with other similarly large bodies to form masses and compose matter of the third element (E3).

For Descartes, matter of the second element (E2) fills most of the visible world and constitutes the heavens (sometimes referred to as celestial matter). Matter of the first element (E1) fills all the interspaces that the parts of (E2), being spherical, leave around them. However, there are more parts of (E1) than are required to fill these places. Consequently, these remaining parts will move toward the centers around which the parts of (E2) revolve (since the parts of (E2) already occupy the places more distant from the center and hence prevent these parts of (E1) from occupying these places) and form at these centers perfectly liquid and rare bodies which in our present visible world constitute the sun and the fixed stars (*LaL*, VIII, 10-12). These bodies, composed purely of matter of (E1), turn incessantly much more rapidly than those of (E2) or (E3) and in the same direction as the parts of (E2) which surround them and have the power to increase the motion of those to which they are nearest and to set them in motion in all directions.

We have already observed that most of the original matter created by God will after a while take the form of (E1) or (E2). The parts that remain to form (E3) will move at the same rate as the matter of the heavens (E2) which contain them, with the largest and most massive among them being compelled to take their courses toward the outer

circles of the heavens containing them and to pass continually thereafter from one of the heavens into another—these are the comets—while the less massive will be pushed in toward the center of the heavens containing them because of the current of the matter of these heavens, where they meet and unite together to form globules whose motion will be the result of the motions that each one of the parts of which they are composed would have had independently (i.e., some parts tend toward the circumference of these heavens, others toward their centers)—these are the planets (*LaL*, IX).

With regard to the planets (*LaL*, X), although they tend toward the centers of the heavens which contain them, they can never reach these centers since the sun and the fixed stars occupy these places. Moreover, since the parts of (E2) which constitute the heavens outside these planets are smaller than those that constitute the planets, they have a greater power to continue their motion in a straight line. The reason is as follows. The tendency of a body to continue its motion in a straight line depends for Descartes not only upon the quantity of matter in each body but also on the extent of its surface. Hence, of two bodies moving at equal speed, if one contains twice as much matter as the other, while it would be true to say that it has twice as much agitation (momentum), it would not necessarily be true to say that it has twice as much power to continue its motion in a straight line. A body whose surface is more than twice as great as another's will always have less power to continue its motion in a straight line (*LaL*, X, 6). Since, then, the spherical parts of (E2) which compose the heavens have the figure which, of all bodies, contain the most matter within the least surface, they will necessarily have the greater force to continue their motion in a straight line.

To summarize the cosmogony of *La Lumière*, matter of the first element (E1) constitutes the sun and the fixed stars (they are luminous bodies); matter of the second element (E2) the heavens (they are transparent); and matter of the third element (E3) the planets, comets, and the earth (they are opaque bodies).

(II) I want now to turn to the theory of elements in the *Principes*. In Part II, Descartes devotes a lengthy discussion to the notions of space, place, situation, etc. in an effort not only to show that the notion of a void is unintelligible but also to explain more carefully the sense in which the essence of a body is extension (*P*, II, 7-18). It appears that Descartes was not very clear about either of these matters in *La Lumière*, and that is why in his summary in the *Discours* very little discussion of these notions takes place. In the *Principes*, however, he seems to have worked this out quite carefully, and the different style of the *Principes* does not lend itself to the kind of misunderstanding and distortion he feared in *La Lumière*.

As is well-known, Descartes believes that the same extension in length, breadth, and depth which constitutes space constitutes body (*P*, II, 10). The only difference he finds between the notions of space and body is that we often attribute to body a *particular extension*, which we conceive to change place often when it is transported, whereas we attribute to space an extension so general that after having removed the body from this space we do not think we have also removed the same extension from that place, since it seems that the same extension always remains while it is of the same magnitude and figure and while it does not change its situation with respect to bodies external to its place. However, Descartes argues, when we remove from a body (e.g., a stone) all that is not essential to its nature as body (e.g., its hardness, its color), we find that the true idea we have of it consists only in its extension in length, breadth, and depth (*P*, II, 11-12). And this is precisely the same idea we have of space, not only when it is full of body but when we presume it to be empty. Hence, the same extension which constitutes the nature of body constitutes the nature of space.

The difference between space and place, then, for Descartes is simply that by place we mean situation (*P*, II, 13-15); i.e., when we say that something is in a certain place, we mean only that it is situated within a certain determinate region in relation to other bodies which we are using as a point of reference to determine this region.

Descartes believes that a careful analysis of these notions reveals convincingly that the notion of a void is a contradiction or impossibility. There can be no such empty space in the universe because the extension of space does not differ from the extension of body. And since it follows from the fact that a body is extended that it is a substance (i.e., something extended), it ought also to follow from the fact that space is extended that there must be something extended there. We are inclined to believe that there is empty space because, for example (*P*, II, 18), since we believe there is no necessary connection between the vessel and the body it contains, we believe that it is possible to remove all the body from the vessel and yet preserve the vessel in the same state even though no other body succeeds it in the place from which it was removed. To correct this error, Descartes reminds us that while there is no necessary connection between the vessel and the body which fills it, there is an "absolutely necessary connection" between the concave figure that this vessel has and the extension which ought be contained in the concavity. Moreover, Descartes argues, if we were to remove all the body contained in the vessel without permitting its place to be occupied by another body, the sides of the vessel would find themselves so near that they would immediately touch since it is necessary that two bodies touch when

there is nothing between them; i.e., it is contradictory to assert that two bodies are apart (there is a distance between them) but that the distance between them is nothing (since distance is a property of extension which cannot exist without something extended).

This series of arguments confirms also for Descartes that there cannot be any atoms—i.e., parts of matter which are in their nature indivisible, which the "philosophers imagine" (*P*, II, 20)—since, however small one supposes these parts to be, they must nonetheless be necessarily extended, from which it is easy to conceive that there is not one among these parts which cannot be divided into two or more other smaller parts (i.e., they are indefinitely divisible).

In sum, then, once Descartes carefully delineates his understanding of extension, space, and situation, both atomism and the acceptance of a void become outlawed as drastic errors.

It is now possible to turn briefly to the cosmogony of the *Principes*.[21] Descartes supposes that at the beginning God divided all the matter with which he composed the world into *equal parts* whose magnitudes were quite small (*P*, III, 46). Descartes assumes this equality among the parts because he can conceive of no order simpler or easier to understand than a perfect equality (*P*, III, 47). God, then, moves these parts of matter with equal force so that two kinds of motion result: (1) each part of matter rotates around its own center; and (2) many parts of matter, taken together, rotate about certain other centers. The speed with which these parts of matter move is equal to the total quantity of motion that presently exists in the world, since from the beginning God preserves this quantity of motion in accordance with the three laws of nature and the seven rules of impact.[22] Whatever figure these parts of matter originally have, because the force of their movement is such as to cause them to separate upon striking one another and because their size causes them to blunt their angles in striking other parts, many of the parts of this original matter became spheres which Descartes regards as matter of the second element (E2) and calls *boules* (*P*, III, 48, 55). Since, however, there cannot be any empty space in the visible world and since these *boules* are spherical, the small intervals that exist around and between these *boules* must be filled with other parts of matter—the scrapings which resulted from the blunting of the angles of these parts of (E2)—extremely slender and swift and capable of changing figure at every moment in order to adapt themselves to these places around and between these *boules* (*P*, III, 49-50). Descartes regards these scrap-

[21] In my judgment, the cosmogony and cosmology take up most of the last two parts of the *Principes*, Parts III, 48—IV, 186.

[22] See Wallace Anderson, "Cartesian Motion," in *Motion and Time: Space and Matter*, 200-21; and Alexandre Koyré, *Newtonian Studies* (Chicago, 1965), 53-114.

ings as matter of the first element (E1). Some of the parts of this original matter, however, are so large and have such irregular shapes that they resist division and consequently cannot be easily changed. These constitute yet a third kind of matter (E3).

Now, the more the parts of (E2) rub against one another and become spherical, the more scrapings (parts of (E1)) are generated (*P*, III, 54). After all the angles of these parts of (E2) have become blunted so that they form spheres, they occupy less space than they did before they became spherical and they begin to move away from the center about which they revolve, not only because of their tendency to move in the direction of a straight line but also because the scrapings of (E1) which have moved to the center push the more slowly moving *boules* away from the center in all sorts of directions (i.e., the agitation of the parts of (E1) is always greater than that of (E2) so that it is always easy for any of them to pass through the small intervals which the parts of (E2) have around them and consequently reach the center faster than these parts of (E2)) (*P*, III, 68-72). Since there will be many more scrapings than are needed to fill the spaces around these *boules*, many of them which have moved to the center remain there and compose very subtle and liquid bodies, namely, the sun in the center and the fixed stars in other centers.

However, the parts of (E1) are not equally agitated and are not all of the same size (*P*, III, 88). Those which are smaller and least agitated move in a straight line from the poles of each vortex toward its center and remain at rest relative to these other parts and eventually join together to comprise certain small bodies, which Descartes calls "striated" or "channelled" parts (*P*, III, 89-90). He conceives of these striated parts as small columns, whose cross sections are curvilinear triangles with concave sides, with three furrows or canals on their sides in order that they can pass in turning through all the small intervals which exist between three *boules* which touch one another and which consequently have the figure of a curvilinear triangle (*P*, III, 92).[23] The three canals on the surface of these striated parts must be turned face to face like a shell, according to the way in which these striated parts pass through the paths which more or less extend along the axis of their movement—those coming from the north pole must be turned differently from those coming from the south pole. Consequently, the pores through which the striated parts of one pole pass are not able to receive the striated parts of the other pole, for like a screw-nut of a screw the pores are deepened within in such a way that only striated parts which have their canals or furrows turned in a

[23] This is the excellent description of E. J. Aiton, *The Vortex Theory of Planetary Motion* (New York, 1972), 48 ff. See also René Dugas, *Mechanics in the 17th Century* (Neuchatel, Switzerland, 1958), 179 ff.

certain way can pass through. By means of these striated parts, Descartes explains the appearance and disappearance of spots on the sun (*P*, III, 94-118) as well as the properties of magnetism (*P*, IV, 133-86). I shall restrict my attention to his account of spots on the sun.

All the most subtle matter of (E1) which comprises the sun and the stars moves together very quickly and causes the striated parts (and other parts of (E1) which are not quite as heavy as these striated parts) to be rejected from the center and to attach together and float on the surface (much like the scum which floats on the surface of a liquid when it is boiling), losing there the form of (E1) and taking the form of (E3). When these parts, thus transformed, are in great quantity, they impede the action of the light of the sun and compose spots similar to those which had been reported by Galileo and Scheiner.[24] Descartes believes that, with the exception of the region of the sun toward the poles, all of its surface is ordinarily covered with this kind of transformed matter but that technically only those places where it has become so thick as to impede the transmission of light ought to be called spots. Accordingly, Descartes believes these spots are more likely to appear on the sun toward the ecliptic than toward its poles and have very irregular and changing figures. Sometimes, in fact, it can happen that these spots become so large that for a period of time they cover the entire surface of the sun, which helps to explain for Descartes why the sun may appear at certain times more pale than usual and why some stars seem to disappear and other seemingly new ones appear (like that reported in 1572[25]).

Now, just as many liquids as they continue to boil dissipate the scum that they had formerly produced, so the spots are destroyed with the same ease, since they are composed only of this newly transformed matter which is very unstable (*P*, III, 96). When these spots break up, the parts into which they are divided are not entirely similar to those with which they had been originally composed (*P*, III, 99). Instead, some become quite small (and hence massive and solid, since their points are broken off) and pass easily between the parts of (E2) in order to proceed toward the centers of the neighboring vortices. Others become even smaller, since they consist only of these points which have broken off the former parts, and pass in all directions toward the sun (sometimes they are even driven back toward the sun and serve to augment its pure substance). Others, however, remain quite large, since they are composed primarily of striated parts and are not able to pass through the small intervals around the

[24] See his letters to Mersenne, 15 April 1630 (*AM*, I, 128-37) and February 1634 (*AM*, I, 250-51).

[25] See his letter to Mersenne of 10 May 1632 (*AM*, I, 225-27).

boules and consequently enter the places of these *boules* to take the form of (E3) and form a very rare body (similar to the pure air that exists above the clouds) which surrounds the sun on all sides extending to the sphere of Mercury. However, this rare body does not grow indefinitely, since the agitation of the *boules* which pass around its parts dissipates as many of these parts as come to it. However, eventually (*P*, IV, 1 ff.) this body becomes quite thick and heavy and consequently compels the matter transformed into (E3) to remain beneath it and to form together in layers until finally it forms a body, darkened and covered with a kind of crust, which is presently our earth. In this way, the earth was originally, in Descartes' mind, a star. Such, in brief, is the cosmogony (and bits of the cosmology) of the *Principes*.

(III) When we compare the theory of elements in the cosmogonies of *Traité de la Lumière* and the *Principes*, we find some important revisions and additions.

(1) In the first place, whereas in *La Lumière* Descartes had associated his three elements with the more traditional ones—(E1) with fire, (E2) with air, and (E3) with earth—in the *Principes* he completely avoids this association. Moreover, while he finds it necessary in delineating his theory of elements in the prefatory chapters of *La Lumière* to discuss the problem of the status of elements in mixtures or compounds, in the *Principes* he completely avoids that discussion.

Both of these changes are indicative of a shift in intellectual milieu and Descartes' own assessment of the novelty and orthodoxy of his views. At the time at which Descartes was framing the basic principles of his philosophy of nature, especially during his stay in Paris from 1625 to 1628, both the questions of the nature and number of elements and of the status of elements in a mixture were of considerable importance. Since the renaissance and rehabilitation, so to speak, of atomist and anti-Aristotelian theories of matter, these problems had naturally come under attention. Descartes' more conciliatory style in *La Lumière* dictated, I believe, an attempt to associate his theory of elements in some way with the more traditional accounts of elements in order to safeguard his own position from heresy. Descartes came to see, however, by the time he was writing the *Principes* that this association invites both the misunderstanding and distortion he fervently sought to avoid. Consequently, in the *Principes* he avoids the comparison altogether.

Similarly, I believe Descartes came to see that his theory of elements rescued him from the puzzles about the status of elements in a mixture then current. To understand how this is so, it is necessary to say something more about the theory of elements.

In a very real sense, there are not three elements—there are rather *three forms of the one matter* with which God created the

universe. By this I mean that the three elements (E1, E2, and E3) are in reality only parts of original matter which have taken on, over time (as a result of collisions, etc.), different sizes and figures and move at different rates of speed. For example, (E1) is composed of the same matter as (E2). It differs from (E2) in its size, figure, and movement—the parts of (E1) are smaller than those of (E2); they adapt more easily than those of (E2) and consequently have no determinate figure (while (E2) are spherical); they move much more rapidly than those of (E2). These parts of (E1) are simply bits of matter that have broken off, little by little, the original matter God created. Similarly, for (E3). Strictly speaking, then, Descartes' philosophy of nature is a kind of monism.

This helps us to explain the sense in which parts which were (E1) can be transformed into parts of (E3), and other parts of (E1) can become striated parts. When Descartes posited this theory of elements in *La Lumière*, he felt constrained to discuss the problem, then current, of the status of elements in a mixture. I believe he became dissatisfied with that account and came to realize that his theory of elements did not pose a problem in this regard. That is, the problem inherited from Aristotle of the changeability of the elements in a mixture, vigorously denied by the proponents of the new philosophy of nature, was no cause of concern for Descartes. Since the elements were merely the *same parts of matter*, but of different size, magnitude, and motion (*all different states*), there is nothing prohibiting a part which has a certain size, figure, and motion at one time from taking on at another time, as a result of collisions in accordance with the basic laws of nature (and, in the *Principes*, with the rules of impact)—which explain the *changes of state*—another size, figure, and motion.

(2) Secondly, whereas in *La Lumière* Descartes was reluctant to reject the existence of a void, in the *Principes* the nonexistence of a void becomes one of the central principles of his philosophy of nature. The shift is important because it eliminates, I think, a potential gap in his theory. In *La Lumière* Descartes restricted his attention to that determinate region between the earth and the stars of the principal heaven because he was uncertain whether a void existed *beyond* this region. A natural question arises here, however: *If* a void exists beyond this region, how would this affect Descartes' cosmogony (especially his theory of vortex motion)? Such a question reveals a potential gap in Descartes' account in *La Lumière*. In the *Principes*, however, there is and can be no void *anywhere* in the universe. Hence, the question never arises and the gap disappears.

Moreover, given the impossibility of a void *anywhere* in the visible world and given the three laws of nature, Descartes can now more easily explain the sense in which all motion is in some sense circular

(as in a vortex) even though each body tends to move in the direction of a straight line, since every body which tends to move in the direction of a straight line will be prevented from doing so by the resistance of other bodies it meets with similar tendencies so that its motion will be along a circular path (the particular path depending on the size and speed of the body). If, however, a void were to exist beyond the heaven of which the earth and the stars are a part, it would be necessary for Descartes to seek some other explanation for this circularity (vortex motion) or at the very least to take account of motion in *that* region or to consider its effect on the region beneath it, in which the earth resides.

(3) Thirdly, in *La Lumière* it is not entirely clear why the smallest parts of (E1) are so easily adaptable as to change figure at every moment. But in the *Principes* these parts are now described as *extremely slender* in figure which, coupled with Descartes' rule about surface areas (i.e., the more surface area a body has, assuming the equality of size and speed, the more easily it is divisible by other bodies it meets and hence adaptable) helps clearly to explain this adaptability.

(4) Fourthly, Descartes came to realize that he must explain more carefully the nature of the changes of state produced in collisions. Consequently, while he claimed in *La Lumière* that such rules of impact were formulable but did not delineate them (*LaL*, VII, 20), in the *Principes* he develops them explicitly (*P*, II, 46-52) and makes extensive use of them throughout his cosmology.

(5) Finally, a word is in order about the relationship Descartes sees between his cosmogony and the immutability of God, since this helps to put his reasons for suppressing publication of the *Traité* into broader perspective. The descriptions Descartes proffers of this relationship in *La Lumière* and *Principes* are substantially the same (*LaL*, VII; *P*, II, 36-42). In both, Descartes claims that the three laws of nature are derivable from the fact that God is immutable (although it is not at all clear how this is so). In both, Descartes conceives of God's immutability as God's act of continually conserving matter by the same means by which he created it. In both, the laws of nature (and, in the *Principes*, the rules of impact) seem to be descriptions for Descartes of these means. In both, God imparts to each part of matter the tendency to move in the direction of a straight line and the tendency to persevere in the same state. In both, God conserves the total quantity of motion in the universe. In both, the original states of parts of matter are of little consequence to his cosmogony, since over the course of time, in accordance with the laws of nature and the rules of impact, Descartes believes that their motion will result eventually in the present orderly arrangement—although in the *Principes* Descartes is more inclined to believe that God created the parts of

matter of equal size and imparted to them equal speed, since such original states of matter would render the transformation into the present arrangement more efficient (but, again, it is not at all clear how or why this is so). As far as I can tell, then, the accounts differ very little. An important difference between the accounts in *La Lumière* and the *Principes*, however, is the context each provides for the presentation of these theological views. In my judgment, Descartes became increasingly convinced that the different style of the *Principes*, the clearer development of his rejection of the void and atomism, the addition of his rules of impact, and the sharpening of his theory of elements to include the notion of striated parts, would allow the theological orthodoxy of his cosmology to surface more readily than the presentation in *La Lumière*. Hence, his reluctance to publish these views disappeared.

(**IV**) To summarize, an important ingredient in Descartes' philosophy of nature is his theory of elements, initially developed in his *Traité de la Lumière* (1633) but sharpened and revised in the *Principes* (1647). At the time at which he wrote *La Lumière* he was quite fearful that his corpuscularian theory of matter would be taken as just another heretical form of atomism, his theory of elements confusedly linked to more traditional accounts, his reservations about the existence of a void interpreted to mean that a void was possible, and finally his genuine belief in the immutability of God construed at best as mere theological capitulation or at worst heresy. By the time he wrote the *Principes*, however, Descartes was certain that he could prove that a void could not exist anywhere in the universe and then found it possible, with a more careful delineation of the claim that extension is the essence of a body, to refute atomism, and finally, adding specific rules of impact to his laws of nature and sharpening his theory of elements by including the notion of striated parts, he realized more clearly than ever the ultimate explanatory power and theological orthodoxy of his philosophy of nature. What might be called, following Dijksterhuis, Descartes' "mechanicism" was complete and tight.[26]

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[26] E. J. Dijksterhuis, *The Mechanization of the World-Picture* (Oxford, 1961).